# Introducing irrigation in the dry farming systems of Lanzarote (Canary Is., Spain): the impact on tephra-mulched soils

Tejedor, M.[1] – Jiménez, C. – Fuentes, J. – Neris, J. – Hernández-Moreno, J.M.

[1]Dpto. Edafología y Geología, Facultad de Biología, Universidad de La Laguna, Islas Canarias, España.
Phone: +34 922318629; Fax: +34 922318368; E-mail: martesa@ull.es

## 1. Abstract

The extreme aridity and scarcity of water resources of the island of Lanzarote has led to the development of a traditional dry-farming system, based on soil mulching with basaltic tephra (*arenados*). This system is sustainable, conserving both water and soil, while also improving salinity and soil temperature characteristics. In recent decades, the increased availability of desalinated (DW) and reclaimed wastewaters (RW), which account for 99% of island's water resources (20.7 $hm^3year^{-1}$), has caused a change in the management of this system due to the introduction of irrigation. The present work aimed to evaluate the impact of irrigation on soil and crop quality in the *arenados*. The main characteristics of the DW were EC (880-1078 $\mu Sm^{-1}$), SAR (7-10 $meqL^{-0.5}$) and B (≈ 1 $mgL^{-1}$). Consequently, the municipal wastewater with tertiary treatment (RW) also presented high values for SAR (6-14 $meqL^{-0.5}$) and boron (0.7-1.3 $mgL^{-1}$), as well as salinity levels of between 660-1874 $\mu Sm^{-1}$. In order to evaluate the influence of irrigation on the soil quality, eight field plots were selected and in each one the drip-irrigated and non-irrigated subplots, both of which were covered with basaltic tephra, were compared. Soil samples were taken at 0-10 and 10-30 cm. The results showed a significant increase in salinity in the RW-irrigated soils, especially in the surface layers, with values exceeding 5 $dSm^{-1}$. The same tendency was observed in the case of DW irrigation, although here the EC values were below 2 $dSm^{-1}$. In general, SAR values increased with irrigation, especially under RW. Both hot water soluble and soil solution boron increased significantly with irrigation and levels considered toxic were reached in some cases. However, no phytotoxicity symptoms were observed in the crops.

The results reveal an increasing degradation of the soil quality in the mid/long-term as a result of irrigation, particularly with regard to boron. This study should be extended to other irrigated areas in order to verify the observed trends, in which case the sustainability of the *arenados* would not be guaranteed under current management practices.

## 2. Introduction

In Lanzarote, one of the most arid islands in the archipelago of the Canary Islands, a traditional farming system - known locally as *arenados* - based on soil mulching with basaltic tephra has been in use since the 18$^{th}$ century. Thanks to its benefits for soil and soil water conservation, the system has permitted a form of dry-farming agriculture with acceptable productivity. Previous work by the authors has shown that it can greatly reduce soil salinity and sodicity, through positive modification of the soil moisture and temperature regimes (Tejedor et al., 2002, 2003a, 2003b, 2004; Díaz et al. 2004, 2005). These properties make this dry-farming system highly sustainable.

Due to the very arid climate, water is extremely limited on Lanzarote. In spite of local policies for conservation and restoration of the traditional agricultural landscapes, the availability of new water resources has led to a more intensive form of agriculture. Over the past few decades the availability of RW and DW has allowed irrigation networks to be established and the total area under irrigation (mainly drip) is currently estimated at approximately 12500 ha.

The aim of the present work is to analyse the impact of the change from dryland farming to irrigation in soils covered with basaltic tephra mulch.

## 3. Methods

### *3.1. Site description*

The volcanic island of Lanzarote is the easternmost in the archipelago of the Canary Islands (Spain). It measures 846 $km^2$ and lies between 28’50 and 29’15 north latitude. Annual rainfall is below 150 mm, and the climate is characterised by high evapotranspiration (> 2000 mm), high relative humidity (70% on average) and an average annual temperature of approximately 20ºC, with considerable day-night differences. Winds are predominantly N and NE with average velocities of between 5 and 7 $ms^{-1}$. The average number of hours of daily sunshine is 7.8.

Eight field plots were chosen for this study, six of which were under irrigation using recycled wastewater (RW) and two with desalinated water (DW). Irrigation with RW first began about 8-10 years ago, and with DW between 20-30 years ago. In all the field plots, subplots under drip irrigation were selected along with non-irrigated counterparts. Both had basaltic tephra mulch coverings and were used primarily to grow sweet potato (*Ipomoea batatas)*. In the irrigated plots, one to two crops per year can be obtained, whereas in the non-irrigated ones only an average of one crop every two years is possible. Water is distributed mainly by drip irrigation (flow rate of 4 L $h^{-1}$). The irrigation, doses and frequency, varies depending on the stage of crop development and climatic conditions. In both systems fertilization is limited to manure and ammonium nitrate or sulphate at the time of planting.

*3.2. Sampling and laboratory analysis*

Soil samples were taken at two depths (0-10 cm and 10-30 cm) from the soil-mulch interface. At each depth ten samples were taken in each field plot. The following soil parameters were studied using USDA methods: Organic carbon (OC), Olsen-P, Kjedhal-N, hot water-soluble Boron (HWSB), Fe, Mn, Cu, Zn, calcium carbonate, mechanical analysis and exchangeable cations. PH (pHs), EC (ECs), Boron (Bs) major cations and anions were determined in the saturated paste solution.

Urban RW (tertiary effluent) from the towns of Arrecife and Tias was used for irrigation. The origin of these waters is desalinated seawater (obtained by reverse osmosis). Water analysis was performed in accordance with Standard Methods.

**4. Results**

Chemical analysis of the recycled wastewater revealed that it is poorly suited to irrigation, due mainly to the high salinity, boron and chlorides (Table 1). Based on the USEPA (2004) and New Zealand/Australia (ANZECC and ARMCANZ, 2000) guides, the quality of the waters poses a number of short-term risks. In addition, the waters are highly variable in terms of quality, thus making management recommendations difficult. Table 1 shows the highest and lowest values obtained for the most important parameters in the monthly samples taken of the wastewater used for irrigation. The trace elements Fe, Al, Cu, Mn, Ni, Pb, Zn were also determined for all the samples, although no risks were observed.

**Table 1 Parameter range for reclaimed water**

| Parameter | | Parameter | |
|---|---|---|---|
| pH | 6.8 – 8.3 | $Cl^-$ (meq$L^{-1}$) | 3.7-11.9 |
| CE (µS $cm^{-1}$) | 660 - 1874 | $SO_4^{2-}$ (meq$L^{-1}$) | 0.5 - 4.0 |
| $Ca^{2+}$ (meq$L^{-1}$) | 0.1 -1.6 | P-$PO_4^{-3}$ (mg $L^{-1}$) | 0.1- 7 |
| $Mg^{2+}$ (meq$L^{-1}$) | 0.4 -1.5 | N-$NO_3^-$ (mg $L^{-1}$) | 3.4 – 19 |
| $Na^+$ (meq$L^{-1}$) | 4.5 - 11.3 | N-$NH_4^+$ (mg $L^{-1}$) | 0.0 – 18.7 |
| $K^+$ (meq$L^{-1}$) | 0.4 - 1.2 | B (mg $L^{-1}$) | 0.15 – 1.32 |
| SAR (meq $L^{-0.5}$) | 6 -14 | DQO (mg $L^{-1}$) | 13.3 – 68.4 |
| Alkalinity (mg $L^{-1}$) | 0.8 – 3.6 | DBO (mg $L^{-1}$) | <5 – 38.1 |

In the case of DW, the most important risks observed, indicating light to moderate restriction, were associated with salinity, sodification and boron (Table 2)

**Table 2 Parameter range for desalinized water**

| Parameter | | Parameter | |
|---|---|---|---|
| pH | 7.1– 8.1 | $CO_3^{2-}$ (meq$L^{-1}$) | 0 |
| CE (µS $cm^{-1}$) | 880-1078 | $HCO_3^-$(meq$L^{-1}$) | 0.4 - 0.8 |
| $Ca^{2+}$ (meq$L^{-1}$) | 0.2 -0.5 | $Cl^-$ (meq$L^{-1}$) | 6.7-8.7 |
| $Mg^{2+}$ (meq$L^{-1}$) | 0.6 -1.6 | $SO_4^{2-}$ (meq$L^{-1}$) | 0.3 – 1.1 |
| $Na^+$ (meq$L^{-1}$) | 4.5 – 8.0 | SAR (meq $L^{-0.5}$) | 7-10 |
| $K^+$ (meq$L^{-1}$) | 0.1 – 0.3 | B (mg $L^{-1}$) | 0.7 – 1.0 |

Table 3 sets out selected properties of the soils under dryland conditions and under DWR irrigation

**Table 3 Selected properties of the studied soils**

| | pHs | Olsen P (mg kg$^{-1}$) | OC (g kg$^{-1}$) | N (g kg$^{-1}$) | $CaCO_3$ (g kg$^{-1}$) | Clay (g kg$^{-1}$) | Silt (g kg$^{-1}$) | Sand (g kg$^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| **Depth** | | | | **Rainfed soils** | | | | |
| 0 – 10 | 6.7 - 7.8 | 4.9 - 51.2 | 1.6 - 7.5 | 0.3 - 0.9 | 1 - 77 | 125 - 346 | 351 - 545 | 128 -524 |
| 10 - 30 | 7.1 - 7.9 | 1.5 - 14.4 | 1.4 - 5.6 | 0.4 - 0.8 | 1 - 134 | 227 - 566 | 367 - 562 | 61 - 304 |
| | | | | **Irrigated soils** | | | | |
| 0 – 10 | 7.0 - 8.1 | 3.0 - 66.5 | 2.1 - 7.7 | 0.3 - 0.9 | 1 - 93 | 168 - 378 | 161 - 563 | 93 - 521 |
| 10 - 30 | 6.8 - 8.2 | 2.3 - 39.7 | 1.4 - 5.3 | 0.4 - 0.7 | 1 - 130 | 153 - 734 | 217 - 562 | 43 - 531 |

In the non-irrigated systems the EC values were generally below 1 dSm$^{-1}$, with low variability (Fig. 1). However, when irrigated with RW an increase in salinity, along with a significant increase in electrical conductivity, can be seen, particularly deeper down (0.3-1.0 dSm$^{-1}$ in non-irrigated soils, 0.5-4.0 dSm$^{-1}$ in irrigated soils). An important increase in the variability of the EC values was also observed under irrigation, which can be attributed to the irrigation management (periodical shift of the liners).

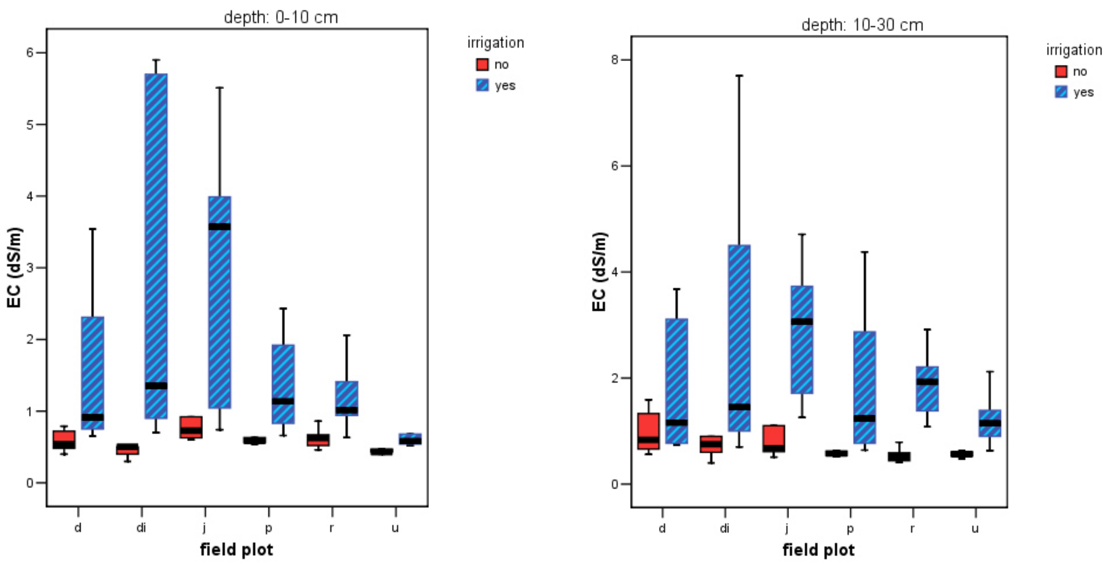


**Figure 1 Comparison of electrical conductivity in saturated paste between irrigated and rainfed fieldplots at two depths (Note different scale for y-axis)**

SAR values also increased with irrigation, both on the surface and at depth, except in two field plots. These also presented a different behaviour in terms of the pH and alkalinity of the soil solutions, which decreased on irrigation, particularly on the surface.

Statistical analysis of the micronutrients in the irrigated and non-irrigated soils did not produce significant differences at any of the studied depths, except in the case of boron. Fe, Cu and Zn values are adequate, unlike those for manganese, which are high even though the soils are alkaline and carbonated.

Both hot water soluble B (HWSB) and soil solution B (Bs) increased significantly with irrigation (Fig.2). Although most of the samples were below B critical toxicity limits, some of the field plots are approaching these values. Although, as mentioned, there is a clear increase in concentrations of boron in the irrigated soils, no phytotoxicity symptoms were seen in the crops.

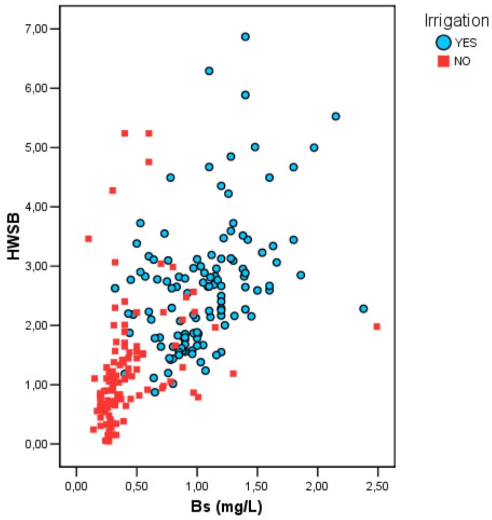


**Figure 2 Relation between boron in soil solution and hot water soluble boron in the irrigated and non-irrigated fieldplots**

In the DW-irrigated soils an increase in salinity and in the SAR was seen in the irrigated plots, although statistically significant differences in the CEes were recorded in only one of the plots at surface level. Chlorides and sulphates increased with irrigation, with statistically significant differences found at both depths sampled in one of the two plots and at depth only in the other. Bs and HWSB also increased under irrigation. Statistically significant differences were obtained for Bs and HWSB in the two plots and at both depths studied, with values nearing toxicity levels in one case.

The results obtained reflect increasing degradation of the soils under irrigation, a finding which calls into question the medium-long term sustainability of 'arenados' irrigated with these non-conventional water resources, based on current management practices. It is envisaged that irrigation of this type will be extended to other parts of the island, given the increased yield, but this will bring an increased threat of desertification. Given the situation, a campaign has been set in motion to disseminate the results of the study among the authorities and the sectors concerned.

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